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THE UTILIZATION OF THE NITROGEN AND ORGANIC MATTER IN SEPTIC AND IMHOFF TANK SLUDGES

BY

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THE UTILIZATION OF THE NITROGEN AND ORGANIC MATTER IN SEPTIC AND IMHOFF TANK SLUDGES

BY

C. B. LIPMAN AND P. S. BURGESS

Through the courtesy of Professor Charles Gilman Hyde, Professor of Sanitary Engineering at the University of California and Consulting Engineer of the California State Board of Health, the writers are enabled to give the following brief summary of the sewage and sludge output in California. There were in the state in October, 1913, 157 public sewerage systems, serving a population of about 1,577,100 and in addition there were three sanitary districts with public systems and ten municipalities with private systems. This leaves a balance of sixty-four municipalities with no sewerage systems. Of the communities which dispose of their sewage in some manner only eighty-nine treat the sewage before final disposition thereof. The last mentioned number of communities serve a population of about 284,000, and the balance a population of about 1,300,000. Those communities therefore which dispose of untreated sewage by dumping into fresh or salt bodies of water make up about 78 per cent of the total population served by some kind of sewerage system, the balance (only about 22 per cent), treating the sewage in some manner before finally disposing of it, and even in the latter cases practically none of the treated sewage is employed for agricultural purposes. It must be added here that in forty-six cases representing a population of 195,400, the sewage is used on sewer farms or on irrigated lands.

On the basis therefore of the figures above given, and others it has been calculated that even if the population whose sewage is employed on sewage farms is omitted from the computation and assuming that all instead of only one hundred out of two hundred and thirty-four communities were supplied with septic tanks, there should be produced annually in California about 12,100 tons of dry sludge merely from a population of 1,467,900, which is served by sewerage systems. Using the conventional valuations for the so-called ''plant food'' in the air-dry sludge, the total annual output above roughly estimated should have a value of $108,100.—*Practically none of this goes back to our land today.*

Naturally the suggestion for the use of sludges as fertilizing materials is one of the first ones made, but, such use must be based on some adequate understanding of the agricultural value of the material and that depends not only on the chemical composition of the sludge with respect to nitrogen, phosphoric acid, and potash, but particularly with respect to the condition of "availability" in which those materials are found therein and especially as regards the nitrogenous fraction of the material. In order to carry out the necessary determinations we obtained nine samples of sludge, the description and partial composition of which as determined by us are as given in Table I which follows:

TABLE I

No.	Description	Water and organic matter Per cent	Ash Per cent	Total N Per cent	Nitrate N Per cent	Phosphoric Acid Per cent
1	Orange City Imhoff tank	49.68	50.32	2.66	.012	1.11
2	Fullerton Imhoff tank	25.31	74.69	1.23	.045	.86
3	Anaheim Municipal tank	33.09	76.91	1.54	.115	.99
4	Lindsay septic tank	42.92	57.08	1.83	.090	.89
5	Pasadena Imhoff tank	29.34	70.76	1.68	.135	1.46
6	Orange City Imhoff tank	38.41	61.59	2.38	.060	.77
7	Worcester, Mass., Imhoff tank	43.86	56.14	2.10	.010	1.82
8	Cleveland, Ohio, Imhoff tank	36.37	63.63	1.44	.000	1.28
9	Chicago, Ill., Stock Yards Imhoff tank, 5/14	50.46	49.54	1.73	.400	1.46

It will be noted in Table I that in no case does the nitrogen content of the different sludges exceed 2.66 per cent (based on the air-dry weight of the material), and the average nitrogen content is about 1.84 per cent. The phosphoric acid content of the sludges can be seen by reference to the table, to be even lower than their nitrogen content, and their potash content does not amount to over a few hundredths of one per cent as indicated by an analysis, of the Orange City sludge mentioned in the table, carried out by the Fertilizer Control laboratory of the University of California. The commercial value, therefore of sludge material of the kind under discussion could not be expected to exceed $10 per ton of dry material on the basis of the conventional calculations made by fertilizer chemists.

AVAILABILITY OF THE NITROGEN IN THE SLUDGE

Since nitrogen is the only important fertilizer constituent in the sludge, agriculturally speaking, and since its quantity therein is not great enough per se to render the sludge of great commercial value, it next becomes important to determine the degree of availability of such nitrogen. At the present time the only absolute method of determining the availability of nitrogen in a given fertilizer for a given soil and crop is to test it in experimental plots in the field. Such an empirical method, however, is lengthy and seldom leads to any generalized rule for the use of nitrogenous fertilizers. On the other hand, the arbitrary chemical methods now used to determine "availability" of nitrogen seem to have but little relation to the actual condition of availability of nitrogenous materials, so far as field conditions are concerned.

In these experiments, a new method therefore has been introduced, namely, the determination of the degree to which the nitrogen of the sludge in this case is changed to nitrates by the nitrifying bacteria of the soil. This is undoubtedly a change which all nitrogenous materials in the soil undergo to some extent and our tests therefore will only differ in degree, but not in kind, from those which sludge nitrogen will undergo under field conditions.

As a result of these experiments, we have been able to determine in the case of nine sludge samples obtained through the courtesy of Professor C. G. Hyde, the amount of nitrogen which is actually transformed from the organic form into nitrates in every one of the sludges as tested in three different soil types, one from Anaheim, one from Davis and one from Oakley, California. The sludges were also tested in three eastern soils. The results obtained in the three California soils are set forth in Tables II, III, and IV. The results in the eastern soils are not given here, but are very much the same in nature as those of the California soils, with the exception that a higher availability is obtained for the sludges throughout.

TABLE II

AVAILABILITY OF NITROGEN IN SLUDGES IN ANAHEIM SAND (CAL.)

No.	Description	Nitrate N found after incubation mgs.	Mgs. nitrate nitrogen in Soil	Sludge	Total N in sludge mgs.	N in sludge nitrified mgs.	Per cent N in sludge nitrified
1	Orange City Imhoff tank	8.00	.65	.12	26.6	7.25	27.2
2	Fullerton Imhoff tank	6.00	.65	.45	12.3	5.00	40.6
3	Anaheim Municipal tank	8.00	.65	1.15	15.4	6.20	40.2
4	Lindsay septic tank	5.00	.65	.90	18.3	3.45	18.8
5	Pasadena Imhoff tank	8.00	.65	1.35	16.8	6.00	35.7
6	Orange City Imhoff tank	6.00	.65	.60	23.8	4.75	15.7
7	Worcester, Mass., Imhoff tank	8.00	.65	.10	21.0	7.25	34.5
8	Cleveland, Ohio, Imhoff tank	7.00	.65	.00	14.4	6.35	44.1
9	Chicago, Ill., Stock Yards Imhoff tank, 5/14	6.40	.65	4.00	17.3	1.75	10.1

TABLE III

AVAILABILITY OF NITROGEN IN SLUDGES IN DAVIS CLAY LOAM (CAL.)

No.	Description	Nitrate N found after incubation mgs.	Mgs. nitrate nitrogen in Soil	Sludge	Total N in sludge mgs.	N in sludge nitrified mgs.	Per cent N in sludge nitrified
1	Orange City Imhoff tank	9.00	.25	.12	26.6	8.65	32.5
2	Fullerton Imhoff tank	6.00	.25	.45	12.3	5.40	43.9
3	Anaheim Municipal tank	6.40	.25	1.15	15.4	5.00	32.4
4	Lindsay septic tank	6.40	.25	.90	18.3	5.25	28.7
5	Pasadena Imhoff tank	8.00	.25	1.35	16.8	6.40	38.0
6	Orange City Imhoff tank	7.00	.25	.60	23.8	6.15	25.7
7	Worcester, Mass., Imhoff tank	6.00	.25	.10	21.0	5.65	26.9
8	Cleveland, Ohio, Imhoff tank	5.00	.25	.00	14.4	4.75	32.9
9	Chicago, Ill., Stock Yards Imhoff tank	8.50	.25	4.00	17.3	4.25	24.5

TABLE IV

AVAILABILITY OF NITROGEN IN SLUDGES IN OAKLEY SAND (CAL.)

No.	Description	Nitrate N found after incubation mgs.	Mgs. nitrate nitrogen in Soil	Sludge	Total N in sludge mgs.	N in sludge nitrified mgs.	Per cent N in sludge nitrified
1	Orange City Imhoff tank	9.00	.30	.12	26.60	8.60	32.30
2	Fullerton Imhoff tank	6.00	.30	.45	12.30	5.35	43.50
3	Anaheim Municipal tank	7.00	.30	1.15	15.40	5.55	36.00
4	Lindsay septic tank	4.50	.30	.90	18.30	3.30	18.00
5	Pasadena Imhoff tank	6.40	.30	1.35	16.80	4.75	28.20
6	Orange City Imhoff tank	6.00	.30	.60	23.80	5.10	21.40
7	Worcester, Mass., Imhoff tank	3.00	.30	.10	21.00	2.60	12.40
8	Cleveland, Ohio, Imhoff tank	1.50	.30	.00	14.40	1.20	8.33
9	Chicago, Ill., Stock Yards Imhoff tank, 5/14	6.00	.30	4.00	17.30	1.70	9.80

Several very interesting facts appear in the foregoing tables. Not only do the different sludges behave differently in any one soil, but the different soils manifest markedly different capacities for rendering the nitrogen of sludge in the general sense ''available.'' Thus we find first, that in the Anaheim soil the amount of organic nitrogen in the sludge added which is nitrified, varies from 10.1 per cent in the case of the Chicago sludge to 44.1 per cent in the case of the Cleveland sludge. In the Davis soil the corresponding figures are 24.5 per cent in the case of the Chicago sludge, and 43.9 per cent in the case of the Fullerton (California), sludge. In the Oakley sand the variation is greatest of all, and namely from 8.30 percent, in the case of the Cleveland sludge to 43.50 per cent in the case of the Fullerton sludge. In the second place, it appears that the Davis soil is best suited to sludge, using that term in its general sense again, of the three soils above studied. In no case does it convert less than 24.5 per cent of the nitrogen in the sludge into nitrate, and the total range in degree of nitrifiability of the organic nitrogen in all the sludges tested with the Davis soil is less than 20 per cent. The corresponding range for the Anaheim soil is 34 per cent and that for the Oakley soil a little over 35 per cent. On the other hand, the three soils can scarcely be said to differ in maximum power to render organic sludge nitrogen into nitrate since that is accomplished to the extent of about 44 per cent in every one of them and not beyond. Some other noteworthy differences may be called to the reader's attention, however. While the Davis soil appears to be best suited, from the point of view here considered, for sludges in general, the Anaheim soil transforms 40 per cent or more of the sludge nitrogen into nitrates in the case of three different sludges, whereas the Davis soil does so in but one case as does also the Oakley soil. In general, it must be added that for a ''low grade'' material sludge nitrogen shows a surprisingly high availability even as compared with the best nitrogenous materials as will be further shown below.

COMPARISON OF THE AVAILABILITY OF NITROGEN IN SLUDGES WITH THAT OF COMMON ORGANIC NITROGENOUS FERTILIZERS

In view of the foregoing results of experiments it appears logical to inquire next how the nitrogen of the sludges above discussed compares in availability with that in some of the more important commercial nitrogenous fertilizers of an organic nature. For that purpose we have arranged in Table V data showing the availabilities of the nitrogen in the various sludges used in the California soils of these experiments.

as compared with those of the nitrogen in dried blood, high-grade tankage, low-grade tankage, fish guano, cottonseed meal, and goat manure in the same soils. Table V follows:

TABLE V

COMPARISON OF THE AVAILABILITY OF NITROGEN IN SLUDGES WITH THAT IN COMMON COMMERCIAL NITROGEN CARRIERS

No.	Description	Davis Soil Per cent N available	Oakley Soil Per cent N available	Anaheim Soil Per cent N available
1	Orange City Imhoff tank	32.50	32.30	27.20
2	Fullerton Imhoff tank	43.90	43.50	40.60
3	Anaheim Municipal tank	32.40	36.00	40.20
4	Lindsay septic tank	28.70	18.00	18.80
5	Pasadena Imhoff tank	38.00	28.20	35.70
6	Orange City Imhoff tank	25.70	21.40	15.70
7	Worcester, Mass., Imhoff tank	26.90	12.40	34.50
8	Cleveland, Ohio, Imhoff tank	32.90	8.30	44.10
9	Chicago, Ill., Stock Yards Imhoff tank	24.50	9.80	10.10
10	Dried blood	12.79	.00	4.05
11	High-grade tankage	16.21	.00	3.95
12	Low-grade tankage	27.39	22.70	43.89
13	Fish guano	15.11	trace	4.65
14	Cottonseed meal	14.18	2.00	21.45
15	Goat manure	4.89	3.50	10.39

It is nothing short of striking to note in Table V the great superiority of the sludge nitrogen to that of the other nitrogenous materials when they are compared on the basis of "availability," used in the sense of nitrifiability. Moreover, it is not merely the low nitrogen content of the sludge which brings out the marked contrast just discussed, since the absolute amounts of nitrate produced from sludge nitrogen, are often 50 per cent to 75 per cent as high as those produced from similar weights of dried blood, or high-grade tankage. Studying more in detail the data set forth in Table V we find that low-grade tankage is the only material of the six employed besides the sludges that belongs in the same class with the last named materials from the point of view of nitrifiability. Dried blood and tankage are not nitrified at all in the Oakley soil and but slightly in the Anaheim soil, and the fish guano behaves very much like the other two. Indeed the conclusion seems almost irresistible that the nitrogen of the so-called low-grade materials is most easily rendered available of any of the organic nitrogenous materials. Briefly, therefore, sludge nitrogen is to be considered of greater value, if nitrifiability thereof is any guide at all, than any of the other materials named in Table V, except low-grade tankage and fully as valuable as the latter. This is true when the availability of the nitrogen as measured by nitrification in California soils is used as a criterion, and even more strikingly so when eastern soils are used as pointed out above. The many interesting topics of discussion which arise from a careful consideration of Table V are of far-reaching importance to both the theory and practice of nitrogen fertilization, but the space of this paper will not permit of their consideration here. This may be added, however, that it is not an insignificant fact that the Davis soil throughout, as has already been remarked above, seems to be the one of the three tested which comes nearest to being a generally favorable medium for the nitrification of all the forms of nitrogen but still not the best for some forms of nitrogen.

HOW SLUDGES SHOULD BE USED, ALONE, AND WITH FERTILIZERS

In soils which are rich in the mineral plant foods and are known to be lacking only in organic matter and nitrogen (both total and available) sludge should be used in the air-dry and ground form at the rate of at least one ton to the acre. This should be applied to the land prior to the early spring plowing in the case of orchards and vineyards and prior to fall plowing in the case of grain land. It can be either broadcasted or drilled in. Such applications are particularly to be recommended for the light colored and compacted soils of our hot valleys, the lighter soils needing them the most. The frequency of application can not be recommended in general since ''circumstances will alter cases.'' Individual cases, however, can be prescribed for, if necessary, by the Agricultural Experiment Station on an examination of the soil in question.

In soils poor in phosphoric acid, as well as in total and available nitrogen, the following sludge mixture may be employed per acre:

2000 lbs. finely ground sludge.
300 lbs. superphosphate.

In soils with a high iron content 600 to 800 pounds of Thomas Phosphate powder may be substituted for the superphosphate. If only an addition of phosphoric acid is desired, however, and availability is not a consideration, finely ground steamed bone meal may be substituted at the rate of 1200 pounds per acre for the sludge and phosphate mixture.

To soils deficient in all three of the so-called fertilizer elements (which are not very common in California), or to those "humus poor" soils which do not contain enough available phosphoric acid and potash, the following sludge mixture may be employed per acre:

2000 lbs. finely ground sludge.
300 lbs. superphosphate.
200–300 lbs. sulphate of potash.

Modifications in this formula may be made in accordance with specific cases like those mentioned above.

In soils not notably lacking in nitrogen, but nevertheless deficient in that important element and especially in its available form, the sludge application employed per acre may be reduced to 1000 or 1200 pounds.

CONCLUDING REMARKS

The large losses suffered by our soils through the removal of sludge to the sea or through the direct diversion of sewage into the ocean can hardly be appreciated. According to Elsner and Spillner it has been estimated that the nitrogen alone in the world's sewage which is lost to our soils is worth $143,000,000 annually. While this estimate may be an exaggeration it certainly offers food for thought. What is worse is that money is not only lost by disposing of both sewage and sludge through dumping into the sea, but in most places in which sludge is made by expensive sewage treatment very large sums of money are expended annually for the removal of the sludge to the sea. For example, to quote again the authorities just named, the city of London spends annually $238,000 merely for the removal in tank steamers to the sea of the sludge produced, and the city of Leipzig in Germany spends $7100 per annum mainly for removing dried sludge. In other words, we have throughout the world enormous double waste in taxing town dwellers heavily to treat sewage and remove the sludge on the one hand and then in robbing our soils of their just due by dumping the sludge into the sea.

It is hard to account for the indifferent attitude of municipal specialists and of farmers to the subject of the utilization of sludge. It seems to be difficult now even to give away the material in question and certain municipalities have paid for the removal of the sludge from their septic tanks. What is even worse, much of the material is annually being dumped into the sea. We have not yet learned, as have the Orientals, through the vicissitudes of dire necessity, to conserve our resources. The natural fertility of our soils is still too great, and our acreage too large, to have instilled into us the principles of curtailment of waste. The Chinese and Japanese, as King has so clearly shown in his delightful "Farmers of Forty Centuries," have learned their lesson well by force of circumstances, and scarcely allow anything to go to waste which will help to maintain, no matter in how small a degree, the fertility of their rapidly shrinking acres.

It is sincerely hoped that the evidence set forth above will form another strong argument for the utilization of sludge from municipal wastes and thereby serve to enhance or to maintain the longevity of our soils as profitable crop producers.

For the purpose of setting forth clearly the statistical data with reference to sewage and sludge wastes in California, a special table is arranged for the reader as follows:

TABLE VI

Important Statistics on Sewage and Sludge Wastes in California

Population served by sewerage systems, public and private	1,663,300
Population served by septic tank or other sewage treatment	320,000
Population whose sewage is used on sewer farms, etc.	195,400
Population whose sewage or sludge or both go to the sea	1,467,900
Estimated yield of air dry sludge from latter per annum, in tons	12,054.9
Value of such yield merely on basis of total nitrogen and phosphoric acid contained	$108,494.00
Population whose loss of sewage could be prevented by sewerage systems	1,000,000
Value of sludge from latter per annum	$72,330.00
Total loss of fertility to soils of California on conservative basis	$180,824.00

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